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Large Photometric Sphere

Measurement of the total light output of lighting equipment is made with the integrating sphere, a device by which the light is so thoroughly diffused that the total flux may be determined by a single observation at any selected spot on the sphere. With the increase in physical size of light sources, the National Bureau of Standards found it necessary to construct a sphere large enough to accommodate the largest commercial and research fixtures. The Bureau's new 15-foot integrating sphere, believed to be the largest in the world, has extended the photometric study of light sources to include those beyond the capacity of the Bureau's other spheres, which range up to 7 feet in diameter.

The most useful measure of the value of a light source is the rate at which it supplies light. In the measurement of this luminous flux, all light emitted, regardless of direction, is counted, because present lighting practice utilizes all such flux by means of suitable reflectors. Essentially the method of test is to place a light source or lighting fixture in the center of a standard white-lined spherical room, known as an integrating sphere, and to measure the photometric brightness of a spot on the wall of the room. If the spot observed is screened from the direct rays of the fixture, the photometric brightness of the spot, in the ideal case, varies in direct proportion to the total luminous flux emitted by the fixture.

It would, of course, be much easier to build the room in the form of a cube instead of a sphere. However, any light from a fixture directed initially into one of the

corners of the cube would fail to contribute its full share to the brightness of the inner wall; so the result obtained with a cube would depend on how the fixture was oriented with respect to the corners of the cube. The spherical shape, on the other hand, has the unique property that any flux reflected with perfect diffusion from any part of the inner wall illuminates all other parts of the wall uniformly. Therefore, in an ideally constructed integrating sphere the reflected light flux falling on any part of the sphere is exactly equal to that falling on any other part. It follows that the photometric brightness of any portion screened from the direct rays of the fixture is exactly equal to that of any other such portion. Thus, only one spot need be measured.

All parts of the inner surface of an ideal integrating sphere must have the same reflection factor, and each spot must diffuse perfectly the incident light flux. Furthermore, the ideal sphere must be perfectly empty. In the sphere recently installed at the National Bureau of Standards, great care was taken in applying the sphere paint to the inner wall to insure a coating of uniform reflection factor. The sphere paint was selected especially to give as close an approach as possible to perfect diffusion of reflected light. The reflection factor was kept high so that even if the first component of the reflected flux were to fall somewhat short of the ideal perfect diffusion, the components added by multiple reflection would materially improve the approximation. In addition, the effect of an imperfectly diffus-

ing inner coating may often be minimized by the use of a test method in which the fixture is substituted for a carefully measured standard fixture of the same type.

Obviously, however, the sphere cannot be perfectly empty. The source has finite dimension, and there must be in the sphere the wires and supports for the fixture. There must also be an observing hole in the sphere and a screen between the fixture and the spot on the wall to be observed. If these obstructions are large compared to the area of the sphere, they prevent an appreciable amount of light flux from reaching the observation spot so that the photometric brightness as measured is erroneously low. To minimize this error, the screen between the fixture and observation spot is made as small as possible compared to the area of the sphere wall. Also, the screen, the fixture, the conduits for wires, and the supports are painted with sphere paint, though the light source, itself, cannot be so treated.

The development of large lighting fixtures such as those utilizing the fluorescent lamp emphasizes the difficulties. The 5-foot, 100-watt fluorescent lamp, for example, has a superficial area of nearly 400 square inches. For this area to remain below the desired upper limit of 0.5 percent, the sphere area must be 200 times that of the source. This consideration alone would require a sphere of about 13-foot diameter. There is an added factor that enters into the question. When a full analysis of the details of using the sphere is made, it can be shown that no part of the source should approach too closely the inner wall of the sphere lest appreciable nonuniformities in brightness be produced. All these factors lead to the conclusion that the sphere



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Increase in the physical size of light sources has required the construction of a 15-foot integrating sphere at the Bureau for measurement of total light output. The sphere, believed to be the largest in the world, is made of waterproof molded mahogany plywood.

diameter should be at least 50 percent longer than a thin cylindrical source.

The inside dimensions of the Bureau's 15-foot sphere, weighing more than a ton as installed in a specially designed high-ceilinged room of the new Materials Testing Laboratory, is accurate to within $\frac{1}{4}$ inch along any diameter. Made of molded mahogany plywood, the sphere is composed of 24 identical segments with two polar caps to permit lowering or supporting large fixtures in the sphere. One half is movable and opens on hinges, allowing easy access to lamps and fixtures placed in the sphere for test. The movable half may be completely detached, so that the fixed hemisphere may serve as a hemispherical integrator for special tests. The increased size of the new sphere permits the measurement of cylindrical sources up to 10 feet long.

The use of the fixed hemisphere as a hemispherical integrator has unique advantages in such special tests as determining the quality of searchlight reflectors. A mask with an opening to admit a searchlight beam of the desired beam-spread will permit evaluation of the relative output with only a single reading on each reflector. The beam from an inferior reflector will either be more divergent, indicating poor contour, or contain less flux, indicating poor reflection factor. Thus a lower reading will be obtained, since in both cases a smaller amount of light flux enters the hemispherical integrator.

Telescope Flexure Plate Mounting

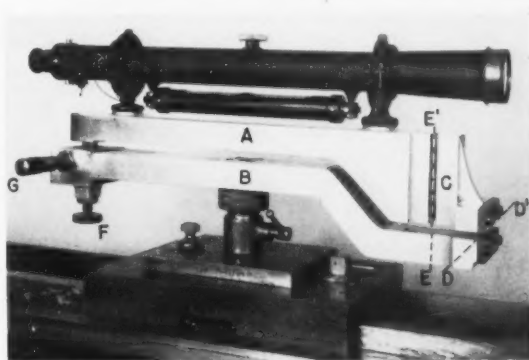
For the exact functioning of a laboratory optical instrument, it is often necessary to provide for the precise angular movement of a part through a small angle in order to obtain a means of fine adjustment. Commercial scientific instruments generally utilize a pair of trunnions and bearings to accomplish such movement. In many cases, however, trunnions can be advantageously replaced by flexure plates. Through an ingenious design of a pair of flexure plates by F. A. Case of the Bureau's optical instruments laboratory, a telescope, with a precision level, has been mounted on an optical bench to serve either as telescope or collimator.

The advantages of the flexure plates over the ordinary type of mounting are many. The more conventional method would perhaps have a conical bearing beneath the center of the telescope for movement in azimuth and trunnions for movement in elevation. The difference in cost of the two types of mounting is largely in favor of the flexure plates. Also, lost motion will never develop in such plates. The ease of movement facilitates the making of fine settings, and the elimination of clamps is most desirable for convenience of operation and prevention of drift. Flexure plates, being near the objective end of the telescope, greatly reduce the lateral shift of the entrance pupil when the telescope is rotated. If trunnions are placed near the objective to prevent such shift, they are very susceptible to damage when excessive mechanical force is accidentally applied to the eye end of the telescope.

The telescope is rigidly attached to an approximately equal length of a dural casting, and a similar piece is rigidly mounted on the slide of the optical bench. These are flexibly connected through a third dural casting by the two phosphor-bronze flexure plates, at the objective end of the telescope, permitting rotation about a horizontal axis in elevation and about a vertical axis in azimuth. In such a telescope-collimator apparatus, it is, of course, necessary to provide for extremely small movements in both directions. Direct adjustment to 0.001 inch, and by a vernier to 0.0001 inch,

is provided at the eye end of the telescope by a commercially available micrometer head. Since the radius from the flexure plate to the micrometer head is approximately 15 inches, 0.001 inch corresponds to about 15 seconds. A spring box, of conventional design, opposes the micrometer head and maintains any setting in azimuth.

Although it is usually desirable to have flexure plates of this type mounted as tension members, the mount could not have been designed in the present neat and compact form had this principle been followed. By designing clamps for the flexure plates so that the portion free to bend is short, the compressional stresses are accommodated without impairment of performance. Measured along its axis of rotation, each flexure plate is approximately $2\frac{1}{2}$ inches wide, a width that is necessary to restrict each motion to the desired plane.



Ingenious application of flexure plates provides a mount for telescope and precision level, which serve also as collimator, and permits extremely fine adjustment in azimuth and angular elevation. The telescope is rigidly attached to the dural casting *A*, with a similar casting *B* mounted on the slide of the optical bench. *A* and *B* are flexibly connected to dural piece *C* by two flexure plates that allow rotation about the axis *DD'* in elevation and *EE'* in azimuth.

Chromated Protein Films Inhibit Corrosion

Chromated protein coatings offering a convenient, inexpensive means of protecting metals—especially zinc, iron, brass, and aluminum—during outdoor storage in mildly corrosive atmospheres have been developed by Abner Brenner, Grace Riddell, and Robert Seegmiller of the Bureau's electrodeposition laboratory. The protective value of such films is somewhat better than that afforded by chemical surface treatments and is much superior to that of corrosion-inhibited oils and waxes. The metallic surface to be coated is first dipped in casein, albumin, or gelatin; the resultant film is then impregnated with chromate, which both hardens the film and inhibits corrosion.

The wartime scarcity of many nonferrous metals led to extensive substitution of ordinary carbon steel for copper, brass, aluminum, and stainless steel in both military and civilian uses. Although the steel was generally protected with zinc coatings, the tendency of zinc to form objectionable corrosion products brought about a widespread use of chromate films on the zinc. These films were formed on the surface by chemical attack in aqueous chromate solutions and, though only a few hundred-thousandths of an inch thick, were useful in inhibiting corrosion. However, as this was apparently due to the presence of minute amounts of soluble chromate, slowly liberated by the action of moisture, it

seemed possible that an enhanced corrosion resistance might be obtained by applying a large quantity of chromate to the metal surface. The electrodeposition laboratory found that proteins offer a good medium for increasing the amount of chromate on the metal surface, since they are basic and readily absorb or combine with chromic acid. Although initially developed at the Bureau as a substitute for chemical surface treatments of zinc, the chromated proteins are also of value in protecting aluminum, steel, brass, and other metals.

The principal constituents of the chromated protein films are a corrosion inhibitor for the metal, a protein that acts as a vehicle for the inhibitor, a hardening agent, and a bactericide to prevent decomposition of the protein. The chromate always serves as the inhibitor and may act as the hardening agent and the bactericide as well. However, other materials such as formaldehyde, tannins, or certain salts of the heavy metals can be used as the hardening agent.

The four functioning constituents of the film can be applied in a single step or in several steps, according to the compatibility of the agents and the degree of protection desired. In the "two-step" process, which is usually the most satisfactory, the metal is first dipped into an aqueous protein solution. When the resulting protein film is dry, it is immersed in an acidified chromate solution for $\frac{1}{2}$ to 3 minutes and allowed to dry without rinsing. The preparation of the protein solution varies somewhat with each protein. Gelatin is dissolved in water by heating gently; albumin may be dissolved in water at room temperature by stirring; casein is dispersed in water and brought into solution with the addition of 25 ml of ammonium hydroxide per liter of solution. The chromate solution contains chromic acid (0.5 to 2 percent) or a dichromate of zinc, iron, or nickel (1 to 10 percent).

A simpler "one-step" method of forming the inhibiting film by a single immersion in a solution containing

both the protein and the chromate has the disadvantage that the solution slowly deteriorates. A solution of this type is made by adding ammoniacal zinc chromate to a solution of casein. The resulting preparation should contain about 10 percent of casein and the equivalent of about 5 percent of zinc chromate.

The chromated protein films are yellow and, unless opaque pigments have been added, are transparent. Their flexibility and adhesion are sufficient to prevent cracking or separation when the metal is bent. They are not injured by heating to 150° C, whereas most chromate films produced chemically on zinc lose much of their protective value at 100° C. Thickness depends principally on the concentration and viscosity of the protein solutions, varying with the type of protein up to about 0.0002 inch. This is in contrast to the proprietary chromate films, which usually are not more than 0.00003 inch thick.

When freshly prepared and hardened, the films are almost insoluble in water and are so hard that they cannot be scratched with the finger nail. Exposure to light further hardens some films and renders them still less soluble. However, the films may be quickly removed from metal parts by application of an alkaline solution such as 5-percent sodium hydroxide. Their removal is thus more convenient and less hazardous than the removal of oil films with toxic or inflammable organic solvents.

The protein solutions, unlike the baths used for direct phosphate or chromate treatments, do not become exhausted and require replenishment, but are fairly stable for long periods. Although chromated protein films are superior to direct phosphate or chromate coatings or to oil films for corrosion prevention, their life is less than that of suitable paint coatings. They are more effective on large, regular surfaces than on the sharp edges and corners of small objects like nuts and bolts, where the film tends to pull away.

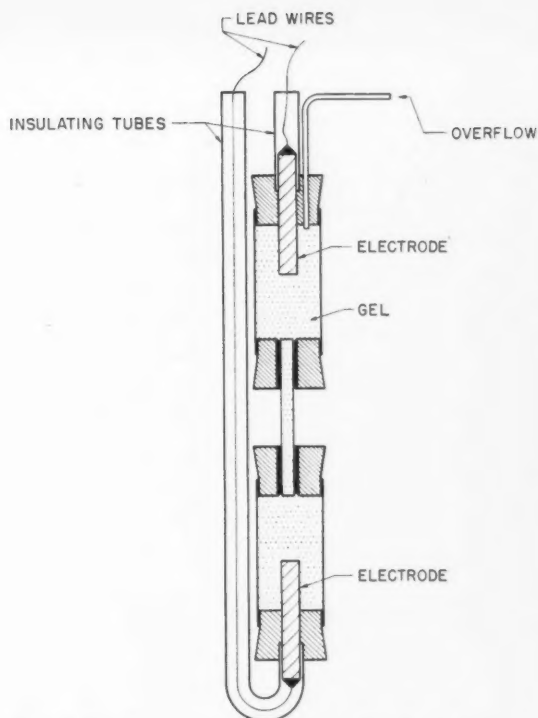
Conductivity Cell for Viscous Materials

A new type of conductivity cell developed by Dr. Earl Otto of the Bureau's electrochemistry laboratory makes it possible to determine with precision the resistivities of viscous liquids, pastes, suspensions, and wetted powders. The apparatus, which also possesses several advantages for use with free-flowing liquids, is simple and rugged in construction, made of inexpensive materials, and so easily and quickly disassembled that its inside surfaces are entirely accessible.

As commercially available types of conductivity cells have been limited to use with nonviscous liquids, studies of the resistivity of the gelatinous pastes and carbon-manganese dioxide mixtures used in dry cells have been confined in the past to investigations of the constituent electrolytes. In recent years dry cells capable of functioning at the low temperatures encountered by aircraft at high altitudes have been urgently needed by the Army and Navy. In connection with the design of several types of dry cells at the Bureau for this purpose, the new conductivity cell was developed to determine

separately the resistivities of dry-cell components at the required temperatures. With some alteration of cell dimensions, it is expected to be very useful in measuring the conductivities of pastes, glues, viscous aqueous solutions, aqueous cement suspensions, pigment slurries, clay suspensions, moistened soil, and other materials. Other suggested applications lie in the textile, plastic, and soap industries and in the manufacture of adhesives, batteries, and ceramics.

In the apparatus designed at the Bureau, the electrodes are made of graphite impregnated with paraffin oil, instead of the more usual platinum. The corrosive action of the ammonium chloride electrolyte used in dry cells and the sturdiness and durability of the carbon electrodes make this desirable. The reservoirs of electrolytic material surrounding each electrode are separated by a small-diameter tube that also contains some of the electrolytic material in order to obtain a cell with a satisfactory constant for use with strong concentrations of highly conductive salt solutions.



Resistivity measurements of viscous liquids, gels, suspensions, and wetted powders may now be made by means of the new, easily disassembled conductivity cell designed at the Bureau. Two glass compartments, separated by a constriction, house electrodes of oil-impregnated graphite, to which the top and bottom lead wires are connected. The overflow tube (at top) simplifies the process of assembling. Rubber stoppers are held in place by springs (right).



The two graphite electrodes, like those ordinarily used in D-size dry cells but shortened to about $1\frac{3}{16}$ inches, are inserted in glass tubes about $2\frac{3}{4}$ inches long and $1\frac{1}{8}$ inches in inside diameter. These larger tubes are joined by a 3-inch tube having an inside diameter of $\frac{1}{4}$ inch, the connections being made with rubber stoppers. The extreme end of each electrode has an electrolytically deposited coat of copper, to which is soldered a lead wire. The leads are protected by glass or plastic tubing, the ends of which are embedded in the top and bottom rubber stoppers. The large glass tubes are graduated to permit insertion of stoppers to the same depth each time the cell is assembled, and the stoppers are connected by springs to prevent leakage of material.

Loading the conductivity cell is not difficult. Free-flowing materials are first poured into the lower electrode compartment. The small-bore middle portion, with top section attached, is then fitted into the bottom section, forcing air and excess liquid through the connecting tube into the top compartment. Additional liquid is poured in to fill the top section, and finally the topmost stopper is inserted, expelling any excess through an overflow tube. With an electrolytic paste the procedure is the same. However, care should be taken to get no paste in the overflow tube, and the paste must be promptly gelatinized by immersing the assem-

bled cell in hot water. A slurry is loaded in the same way as a liquid, except that considerable force may be required to join the two upper sections to the bottom section. A wetted powder requires tamping in all three tubes.

Although the new cell is not unbreakable, it will withstand considerable rough handling. Replacement of any one part requires only a few moments, and some parts may even be replaced without a redetermination of the cell constant. On the other hand, an ordinary conductivity cell requires expert glass blowing to repair a break, and the repair must be followed by replatinizing of the electrodes and a recalibration of the cell.

Although designed primarily for use with viscous materials, the cell also has some advantages for the study of free-flowing liquids. Since it may be wiped dry before loading, there is no need of rinsing with the liquid under test, as is done before a commercial conductivity cell is used. Following a determination the solution may be diluted or otherwise modified and a further resistivity determination made, or it may be returned to storage with very little loss in volume.

The apparatus may be used in conjunction with any of the usual methods of measuring electrolytic resistances. Reproducibility has apparently been limited mainly by the bridge that is used. However, duplicate sets of data have been found to agree within 0.2 percent.

Engineering Principles i

The critical needs of the building industry have focused attention on methods for saving material. In this connection, the strength of houses should be given careful scrutiny, not because houses need be stronger—for few fail—but to judge how much material is superfluous. In carrying out an extensive research program on building materials and structures, the National Bureau of Standards has developed and applied an engineering approach to house design that promises substantial aid to the building industry. This approach, accomplished through application of accepted engineering principles, facilitates the use of unconventional materials and unusual methods of construction.

Strength of houses in the past has been made adequate by patterning them after those that have withstood the test of service conditions. Architects and builders of small structures have followed closely the traditional methods handed down from craftsmen of medieval England. From these traditions, cities have crystallized building codes that are now enforced under the police power of the community.

Except in rare instances, houses have been strong enough to withstand the loads imposed in service. When weaknesses have become apparent, they were more often attributable to defects in relatively small portions of the house than to a general insufficiency of materials. However, available service records do not provide accurate criteria for judging how much excessive material is being used.

Building material is costly as is the labor required to shape and fit it into place. Application of engineering principles to the design of houses presents a complete and logical method for determining allowable loads for walls, partitions, floors, and roofs; and makes it practicable to develop house constructions that have sufficient strength yet require the least amount of material and labor. This is the procedure that is followed in the construction of great bridges and other spectacular structures. Intensities of the service loads are first estimated; each material is then selected to serve a specific function and so distributed as to provide structures of adequate strength at minimum cost. The vast fund of technical information on materials can be utilized similarly for the benefit of dwelling houses when applicable engineering principles and design practices are developed and used.

Suggested methods for designing small houses to have adequate strength without waste of material are described and illustrated in considerable detail in a recent Building Materials and Structures Report¹ of the National Bureau of Standards. Because this is a pioneering attempt to apply engineering principles in the design of houses, further studies will no doubt be needed before universally acceptable methods are developed.

Subjecting complete houses to known loads is very expensive and requires time; therefore, Bureau engineers followed the procedure of applying loads to

specimens that accurately reproduce the most important structural parts of a house. These parts, such as walls, floors, partitions, and roof, have been designated as "elements." For each element, the prescribed methods of loading in the laboratory simulated the actual loads under service conditions. Results of measurements on the structural elements of a house are especially useful to architects and engineers, and approximate closely the results that would be obtained by testing a complete, full-sized house. It is possible, by this method of test, to determine the structural properties of a new construction without waiting for a performance test over a period of years.

In service, house walls are subjected to vertical compressive loads by the dead weight of the walls, floor, and roof above; and by live loads such as wind, weight of snow on the roof, and furniture or persons on the floor. Horizontal transverse (bending) loads caused by the wind act upon the outside faces of such walls and sometimes upon the inside faces.



Application of engineering principles presents a complete and logical application of new materials and unusual construction methods. By applying the most important structural parts of a house, NBS engineers have simulated service conditions. Entire sections of walls, partitions, floors, and roofs have been tested. (left) represent the direct action of wind upon exposed faces, and by intersecting walls against which a wind is blowing. Vertical compressive loads (lower center) are produced by full objects. The structure is subjected to various applicable tests, of which these are typical.

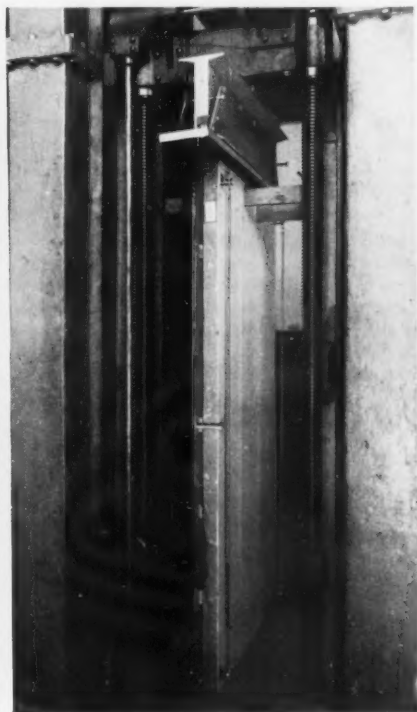
¹ BMS 109, Strength of houses: Application of engineering principles to structural design. Herbert L. Whittemore, John B. Cotter, Ambrose H. Stang, and Vincent B. Phelan. Can be obtained only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

ples in House Design

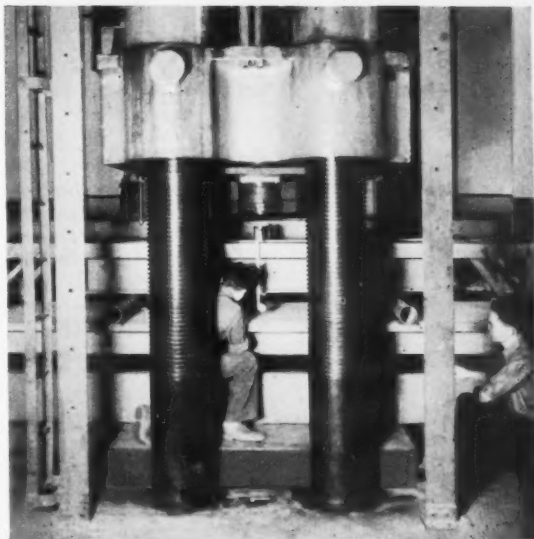
Walls may also be required to withstand concentrated loads, that is, large forces over a small area such as a ladder placed against either face. Impact loads may be applied accidentally to a wall, for example, by a coal truck backing against the outside or by a person or bookcase falling against the inside face. Concentrated and impact loads, to a considerable extent, are unavoidable under service conditions. Racking (shearing) loads are applied to a wall by intersecting walls against which a wind is blowing. This effect is simulated in the laboratory by forces at diagonally opposite corners of the wall.

The same kinds of forces act on load-bearing partitions as on outside walls, but their magnitudes may differ. Non-load-bearing partitions are not designed for compressive or racking loads, which under service conditions, are negligible and may therefore be ignored. However, impact and concentrated loads, through accident, are sometimes applied.

Floors are subjected to transverse, concentrated, and impact loads. Transverse loads result from the weight



and tical approach to the design of dwelling houses, and facilitates loads. y applying known forces to specimens that accurately repro- g engines have simulated the loads that would be applied under service and roof have been tested in Bureau laboratories. Transverse or bend- xpose, and racking or shearing loads (upper center) are applied vertical compressive loads (right) result from many types of forces acting by fall objects or similar causes. Each individual material or con- these e typical.



Floor and roof constructions may be required to withstand transverse loads caused by the weights of objects and persons, and in the case of roofs, snow and wind. The Bureau's largest testing machine is convenient for these tests.

of furniture and persons; concentrated loads occur under the legs of heavy furniture; and impact loads are caused by falling objects or similar causes.

Roofs must withstand transverse and concentrated loads. The former type is caused by wind and the weight of snow or workmen; the latter by the weight of material and tools during construction or repair.

Fundamental data on the wind, snow, and occupancy loads that are likely to be imposed have therefore been obtained, and convenient computational methods developed by the Bureau for estimating the manner in which these service loads are distributed to the different structural elements of houses. That is, for each element of a house, compressive, transverse, and racking loads were computed by recognized principles of engineering mechanics for typical one- and two-story frame houses in several locations representative of extreme wind and snow loads in the United States. Allowable loads (those considered safe) for 100 wall, partition, floor, and roof constructions were then compared with assumed actual loads for the two types of houses in three locations. The comparison shows that some had insufficient strength, and others were much stronger than necessary.

This engineering approach to strength of houses will, it is believed, open the way for designers to introduce unconventional materials and unusual methods of fabrication through laboratory tests to determine whether the constructions possess adequate strength. Such data will greatly shorten the time required to develop and obtain acceptance of new types of construction for houses. At the same time, a substantial saving of materials as well as improved protection against storm damage should result.

Electron Microscopy of Wool Fibers by a Shadowed Replica Method

The National Bureau of Standards is engaged in a broad research program on the causes and nature of wear in textiles. Among the phases under investigation are the degradation effects of various physical and chemical agents. A fundamental approach to the problem is being made through the study of organic fibers by means of electron microscopy. In cooperation with other members of the electron microscopy laboratory and the textile laboratory, Max Swerdlow and

Gloria S. Seeman have developed a simplified shadowed replica technique that is comparatively simple and rapid. Through this technique, fine details of the morphology of the wool fiber, both in its natural state and after various treatments, have been revealed.

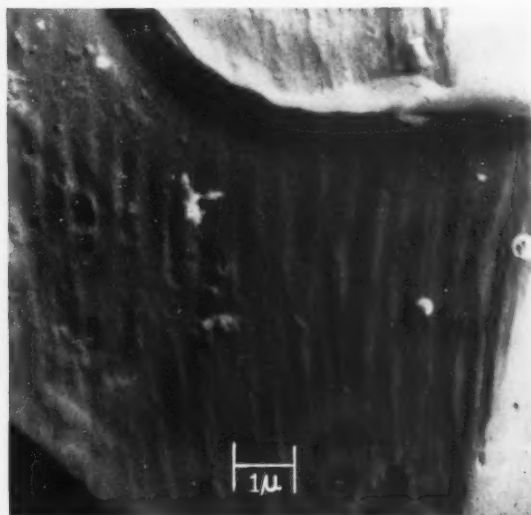
The electron microscope has been a useful tool for observing objects which are thin enough or which are sufficiently small and adequately dispersed to allow the proper scattering and transmission of electrons in the conventional 50-kv microscope. The high resolving and magnifying powers of the electron microscope have thus been used with considerable success in the study of pigments, smokes, viruses, bacteria, and a variety of other colloidal particles. On the other hand, when efforts are made to study organic fibers, ordinary techniques of direct preparation fail.

Partial solutions to the problem have been found by those concerned with the study of wool fibers. Fragments of triturated fibers of reduced and methylated wool are not adversely affected by the intense beam of electrons and are in part transparent to it. Such techniques, however, are very limited. Not only do they preclude the practical prospect of obtaining information about the surface structure of the fiber, but the possibility of giving the same fiber repeated treatment is eliminated because of the mechanical disorganization and chemical alteration produced.

The limitations of direct methods of surface observation by electron optical means has led to the development of ingenious and devious techniques for preparing thin film replicas of the surfaces of electron-optically "opaque" materials. The improvements and variations of the basic replica methods reported by a number of resourceful workers has been successfully applied to the study of many bulk materials. None of these techniques, however, is directly applicable to degraded wool fibers, since the use of excessive heat or crushing pressure in molding the replica introduces undesirable conditions. Moreover, most replica methods involve destruction of the specimen. This too, eliminates the possibility of performing additional treatments on the same fiber.

In order, therefore, to augment the data on the structure of the wool fiber and to correlate these observations

By means of a simplified shadowed replica technique developed at the Bureau, fine details of the wool fiber, both in its natural state and after various treatments, have been revealed. (Top) Chromium-shadowed polystyrene negative replica of a wool fiber taken from unabraded, undyed, fine worsted fabric shows the smooth lacquer-like outer coating of the imbricated scales (total magnification approximately X2300, electron X716, optical X3.2). (Below) Similar ethyl cellulose replica of unwoven, undyed, worsted wool fiber indicates surface degradation associated with the previous history of the fiber (approximately X9000, electron X3600, optical X2.5).



with results previously obtained by the direct disintegration of the fiber as well as by other methods, a simple, rapid, faithful replica technique was developed. This system of specimen preparation successfully combines a method useful for optical and electron microscopy. It involves making a negative replica of the wool fiber in a thermoplastic film which is thin enough to examine directly in the electron microscope and which may be shadow-cast with a suitable metal for added contrast.

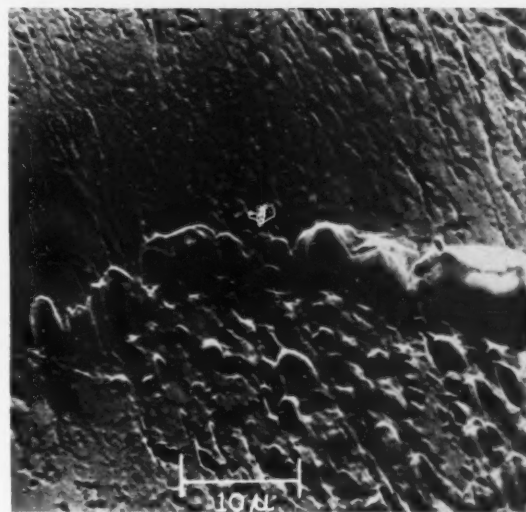
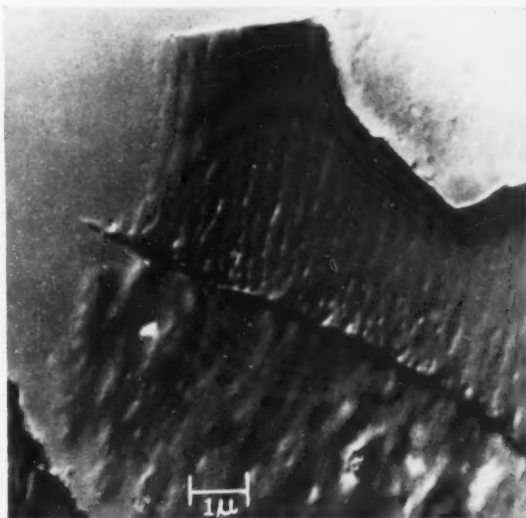
Two thermoplastic materials, ethyl cellulose and polystyrene, can be used with about equal success. When a suitable solution of the resin is poured onto a standard glass microscope slide, a thin film (about 0.4 microns) is formed upon evaporation of the solvent. The separated fibers, free of grease and dirt, are laid upon the thermoplastic lacquer, and another glass microscope slide placed on top of the fibers to make a sandwich with the plastic film. The sandwich can be held together with the aid of a C-clamp. Reasonable care must be exercised in order not to twist the assembly. The clamped glass sandwich of film and fibers is then heated in an electric oven for about 20 minutes at 90° C. The thermoplastic is thus softened to the point where it will flow and form a faithful replica of the surfaces in contact with it. The factors that affect the quality and resolution of the plastic replica are time, temperature, pressure, thickness of the film, and diameter of the fiber. To achieve the proper balance of all these elements is not a difficult problem, inasmuch as the limits of control are not too critical. One or two trials ordinarily provide sufficient experience to make numerous acceptable replicas in a comparatively short time.

After the sandwich has been cooled and separated, the wool fibers usually come away with the uncoated glass slide, or else they can be brushed out. These fibers having once been "fingerprinted" can be saved for further chemical or physical treatment and subsequent replication.

Shadow casting provides added contrast as well as a three-dimensional aspect to the surface details of the replica. A very thin coating of evaporated chromium is deposited obliquely upon the plastic surface. The elevations and depressions in the surface replica cast characteristic shielded radiation shadows, just as their larger counterparts would cast with oblique illumination, for example, the light of the setting sun. Where no metal is condensed, transmission of the incident energy is a maximum. Where thick elevations and ridges occur transmission is a minimum.

(Top) Chromium-shadowed polystyrene negative replica of a wool fiber taken from mechanically abraded, undyed, worsted fabric shows the corrugated underlying structure of the cuticle in contrast to the smooth surface of unabraded fibers (total magnification approximately X8500, electron X3600, optical X2.4). (Below) Similar replica of fiber from undyed worsted fabric after immersion in strong chlorine-water solution shows the blistering Allwörden reaction on the scale surface, with evidence of concentrated attack at the scale endings. Note also the striated understructure of the scales (approximately X9000, electron X3600, optical X2.5—The micron measure on this photo should read 2 μ instead of 10 μ).

The chromium shadowed thermoplastic replicas are then examined in an ordinary light microscope. Photomicrographs may now be taken of them. The glass slide bearing the negative replicas may also be inserted in a photo-enlarger, or desired areas may be selected for further observation in the electron microscope. In the latter case 1/8-inch No. 200 stainless steel specimen screens are placed over the desired areas with the aid of a low-powered microscope. The glass slide bearing the replica and the specimen screens is slowly immersed into a dish of water. The film with the screens still in place can thus be floated free of the glass and retrieved from the surface of the water by turning it over and out with a dry glass slide or a piece of paper. After drying, the thin shadowed plastic replica sup-



ported on the specimen screen is ready for examination in the electron microscope.

Thus, with this method, the structural changes in textile fibers resulting from various chemical and physical factors can be studied. Alterations in surface structure brought about by such factors as abrasion, flexing, repeated loading, acids, alkalis, chlorination, heat, sunlight, moisture, and other elements of degradation may be studied. The manifestations of fiber structure may in turn be correlated with the morphological modifications resulting from actual wear in service. The fundamental problem of the molecular structure of organic fibers cannot be solved by electron microscopy alone, but considerable information may be determined that is of interest to the textile technologist and to those concerned with the subject of wear resistance.

With this in view, attention was concentrated on the study of wool. The wool fiber as shorn from the sheep generally consists of three principal concentric layers—a thin outer covering of scales (cuticle), a middle region (cortex), and a central core or pith (medulla). It has been suggested that the ability of wool fibers to felt, tangle, and curl is dependent upon the direction and shape of the imbricated scale structure, and that the cuticle serves to protect the fiber from chemical and mechanical degradation. It has also been recently suggested that the three dominant cellular structures are encased in an amorphous material that serves both as a matrix and as an intercellular cementum, and that the cuticle layer is in reality covered by this same matrix material.

The present study confirms, at least partially, this theory of the architecture of the wool fiber. Electron micrographs of the surface replicas of mechanically abraded and unabraded wool fibers reveal that the scale is inhomogeneous and consists of a double layer. The outer layer is a smooth covering for the under

structure and shows no specific surface feature. Other investigators have shown this "amorphous plastic layer" to be readily digested in an enzyme as is the featureless intercellular cementum that exists between the scale and the cortex as well as between the cortical cells themselves. The similar reaction to enzymic treatment suggests that these smooth featureless layers are of the same composition.

When this lacquerlike covering is removed by abrasion a rigid striated structure is revealed. The corrugations (ridges and furrows) run more or less parallel to the longitudinal axis of the fiber. They are a feature of the scale itself and are not dependent upon, or a reflection of, the formation and size of the cortical cells. This is borne out by the fact that this corrugated structure is seen in the overhanging portions of the scales under which there is no cortex. Upon additional abrasion, the scales are polished away leaving a smooth filamentary structure with slight vestiges of the former imbricated surface. More rubbing removes the next amorphous plastic layer under the scales and exposes the cortical cells themselves imbedded in the cementum. By this time, the fiber no longer manifests its characteristic filamentary structure and as such is destroyed.

The fabrics studied were mechanically abraded by means of an apparatus² designed by Dr. H. F. Schiefer of the Bureau's textiles laboratory. A rotary disk of parallel, flat metallic strips is applied to the fabric. During the abrasion process fragments of the cloth fall off. This debris as well as the fibers bordering the hole worn into the fabric were examined. Hundreds of specimens were obtained and studied. For easier interpretation of the surface relief, negative prints of characteristic replicas have been prepared for illustration.

² H. F. Schiefer, Solution of problem of producing uniform abrasion and its application to the testing of textiles. *J. Research NBS* **39**, 1 (1947) RP1897.

Atomic Energy Levels

An extensive research program is under way in the Bureau's spectroscopy laboratory to make a complete and up-to-date compilation of the energy levels of the elements as derived from observations of atomic spectra. The data, which will include all information on atomic energy levels accumulated in the past 15 years as well as previously available material, are being published in pamphlet form by the Bureau. As each major portion of the work is completed, these pamphlets will be assembled into volumes of about 500 pages as NBS Circular C467. Section 1 of this circular, Hydrogen through fluorine, which covers 45 spectra, has recently been made available to scientists in related fields.³

A compendium of all known energy levels as derived from analyses of optical spectra is needed by workers in many fields, such as atomic and nuclear physics, astrophysics, chemistry, and industry. Energy levels

of the atom are basic constants of nature that contribute directly to our knowledge of atomic structure. They represent the different values of energy associated with the various possible distributions and motions of the electrons of the atom.

The first book on this subject was published in 1932 by R. F. Bacher and S. Goudsmit. This book, "Atomic energy states", contained the atomic energy levels of 231 spectra of 69 elements—all that had been analyzed at that date. Today this number exceeds 460, representing 82 elements, and the number of known energy levels is greater by a factor of perhaps 4 or 5; yet no complete summary of these data exists. The Bureau is meeting this need through a critically evaluated compilation of all energy levels (exclusive of hyperfine structure ascribed to atomic nuclei), carried out by Charlotte E. Moore of the spectroscopy laboratory. The project is under the direction of Dr. W. F. Meggers, whose broad experience in the field of spectroscopy makes such an extensive program possible. The Bu-

³ Circular C467 is available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 50¢ a copy.

reau is receiving the generous cooperation of numerous scientists both here and abroad, many of whom are furnishing unpublished work on spectrum analysis for inclusion in the publications. Every effort is being made to contact all active workers in the field.

Each chemical element can emit as many atomic spectra as it has electrons. If a pure sample of iron, for example, is placed in an electric arc and the light from the arc is observed through a spectrocope, a complex array of spectral lines of various intensities appears. These lines are produced by the neutral iron atoms and are characteristic of the first spectrum, Fe I.

If iron atoms are excited by an electric spark instead of the arc, the higher temperature of the spark will cause them to lose an electron. The atoms with one less electron in turn exhibit their own characteristic pattern of spectral lines, i. e., the second spectrum Fe II. Similarly, with suitable sources of excitation, spectra of higher stages of ionization can be observed, the total number possible in the case of iron being 26.

The wavelengths or positions of the lines observed in a given spectrum are carefully measured and the corresponding wave-numbers determined. By studying differences among the wave-numbers of the observed lines, the energy levels can be found, since each spectral line is produced by a transition between two such levels. Related levels are grouped according to certain rules to form spectroscopic "terms." The terms result from definite configurations and motions of the outer electrons; for any given configuration the array of terms to be expected can be accurately predicted from the quantum theory. Conversely, the terms furnish information, based on observation, about the outer electrons of an atom. These electrons are involved in the formation of all chemical compounds, and those that penetrate atomic interiors yield information about atomic nuclei.

In May 1946, a meeting of the National Research Council Committee on Line Spectra of the Elements, called by Chairman H. N. Russell, was held at the National Bureau of Standards. The committee discussed details of the program and sent a questionnaire to interested workers in various fields of science regarding the most useful form of presentation of the data on atomic energy levels. The adopted form represents the majority vote resulting from that inquiry.

The spectra are presented in order of increasing atomic number. Under a given atomic number they are listed in order of increasing stages of ionization, i. e., He I, He II, Li I, Li II, Li III. For each spectrum a selected bibliography covering the analysis is given. The energy levels are tabulated in the related groups that form spectroscopic terms, counting upward from the lowest. In the tables, electron configurations are also given, together with term designations in a uniform notation, term intervals, and g -values (magnetic splitting factors found from the observed Zeeman effect). To facilitate cross-reference, the author's term notation is also included when necessary.

For the more complex spectra, charts of observed terms and their electron configurations are included. Similar charts of the terms predicted by theory for the

important isoelectronic sequences are given in the introduction. Comparison of the observed and theoretical terms shows general agreement but also reveals which spectra are incompletely described or analyzed. Besides serving theoretical and experimental scientists as a complete storehouse of identified atomic energy levels, these publications will also be a guide for future research in spectroscopy and atomic physics.

School for Weights and Measures Officials

During the first 2 weeks of March, a school for State weights and measures officials was conducted at the Bureau, the first course of its kind to be held. Emphasis was placed on the fundamental calibration of standards, typical of the work done in the laboratories of the State weights and measures offices. Officials were in attendance from ten States: Council Wooten, Sr., Fla.; William P. Reed, Ga.; James M. Paddock, III., W. Forest Moore, Ind.; J. Fred True, Kans.; William W. Boughner, Mich.; Archie T. Smith, N. J.; Rex H. Mason, Tex.; Robert D. Thompson, Va.; and Charles H. Oakley, Wyo.

Lectures and demonstrations were given by Dr. Wilmer Souder, Chief of the Metrology Division, and associates in the various laboratories of the Division. Dr. L. V. Judson, Chief of the Length Section, who acted as superintendent, was in general charge of the curriculum and coordination of the activities of the school.

It is apparent that a definite contribution in weights and measures technique has been made to the States represented, and that the school met a real need. Because of restricted laboratory facilities, the enrollment for each course is limited to ten individuals. The service will, therefore, be repeated as often as is necessary.

NBS Scientists

Dr. J. Howard Dellinger, Chief of the Bureau's Central Radio Propagation Laboratory, retired on April 30, after 40 years of Government service. When Dr. Dellinger joined the Bureau of Standards staff in 1907, his first work was on the conductivity of copper, at that time a critical matter because of rapidly expanding electrification in the United States. Both the national and international standards subsequently adopted were based on his work. Four years later, he initiated radio research at the Bureau in the same year that an SOS from the sinking Titanic focused public attention on the immediate practicality of radio. A major achievement in the research field was the discovery of the simultaneous occurrence of solar eruptions and radio fadeouts, since called the "Dellinger Effect." Dr. Dellinger is known both in this country and abroad for fundamental research in radio and also for his work with the national and international radio conferences of the past 35 years.

Four members of the NBS scientific staff have been named by the National Research Council to its recently

established Committee on Physical Chemistry. **Dr. Frederick D. Rossini**, Chief of the NBS section on Thermochemistry and Hydrocarbons, and in charge of the American Petroleum Institute Research Projects 6 and 44 at the Bureau, is chairman of the Committee. The NRC Committee on Physical Chemistry, with responsibilities in both the international and national fields, has three subcommittees: Physico-chemical Constants, Physico-chemical Standards, and Physico-chemical Symbols and Terminology. **Dr. George W. Vinal**, Chief of the NBS Electrochemistry Section, is a member of the Subcommittee on Constants; **Dr. Edward Wichers**, Chief of the NBS Section on Reagents and Platinum Metals and Assistant Chief of the

Chemistry Division, is a member of the Subcommittee on Standards; and **Dr. Edgar Reynolds Smith**, Chief of the NBS Physical Chemistry Section, is a member of the Subcommittee on Symbols and Terminology.

The British Embassy has notified **Dr. A. V. Astin**, Assistant Chief of the Electronics Division, that he has been awarded His Majesty's Medal for Service in the Cause of Freedom in recognition of "valuable services rendered to the Allied War effort." Dr. Astin was in England from September 1944 to March 1945 as representative of the National Bureau of Standards and of Division 4, National Defense Research Council. His work during that time involved the use and evaluation of the NBS-developed radio proximity fuze.

NBS Publications

Periodicals⁴

- Journal of Research of the National Bureau of Standards, volume 40, number 5, May 1948. (RP1879 to RP1886, inclusive).
 Technical News Bulletin, volume 32, number 5, May 1948. 10 cents.
 CRPL-D45. Basic Radio Propagation Predictions for August 1948. Three months in advance. Issued May 1948. 10 cents.

Nonperiodical

RESEARCH PAPERS^{4,5}

- RP1871. Determination of sulfur in bone char, Victor R. Deitz, Helen R. Higginson, and Cola Parker. 15 cents.
 RP1872. Effect of support on the performance of vane anemometers, Galen B. Schubauer and Gerald B. Adams. 10 cents.
 RP1873. Heat of combustion of phenyl-beta-naphthylamine (N-phenyl-2-naphthylamine), Donald E. Roberts and Ralph S. Jessup. 5 cents.
 RP1874. Calibration of X-ray measurement of strain, John A. Bennett and Herbert C. Vacher. 15 cents.
 RP1875. Magnetic measurement of the thickness of composite copper and nickel coatings on steel, Abner Brenner and Eugenia Kellogg. 10 cents.
 RP1876. Behavior of experimental zinc-steel couples underground, Irving A. Denison and Melvin Romanoff. 15 cents.
 RP1877. Disintegration of antimony-124, Irving Feister and Leon F. Curtiss. 10 cents.
 RP1878. Stabilization of austenitic stainless steel, Samuel J. Rosenberg and John H. Darr. 15 cents.

APPLIED MATHEMATICS SERIES⁴

- AMS2. Table of coefficients for obtaining the first derivative without differences. Herbert E. Salzer. 15 cents.

CIRCULARS⁴

- C467. Atomic energy levels as derived from the analyses of optical spectra. Volume I, Section 1. The spectra of hydrogen, deuterium, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, and fluorine. Charlotte E. Moore. 50 cents.

COMMERCIAL STANDARDS⁴

- CS100-47. Porcelain-enameled steel utensils. (Third edition. Supersedes CS100-44.) 10 cents.
 CS143-47. Standard strength and extra strength perforated clay pipe. 10 cents.
 CS145-47. Testing and rating hand-fired hot-water-supply boilers. 10 cents.

SIMPLIFIED PRACTICE RECOMMENDATIONS⁴

- R31-48. Loaded paper shot shells. (Supersedes R31-47). 10 cents.
 R62-48. Metallic cartridges. (Supersedes R62-47). 10 cents.
 R229-48. Vises. 10 cents.
 R230-48. Flat veneer products. 10 cents.

LETTER CIRCULARS⁶

- LC895. Simplified practice recommendations. Alphabetical list revised to April 1, 1948. (Supersedes LC883).
 LC896. Standards and specifications for building and construction materials, fixtures, supplies, and equipment. (Supersedes LC860).
 LC897. Transformation of ICI into RUCS coordinates.
 LC898. Gypsum: Technical publications by the staff of the National Bureau of Standards. (Supersedes LC569).
 LC899. European footwear sizes. (Supersedes LC887).
 LC900. Paint, varnish, lacquer, and related products—list of NBS publications and Federal specifications. (Supersedes LC859).

Articles by Bureau Staff Members in Outside Publications⁷

- Electrochemical sources of electric power, parts I and II. George W. Vinal. Electrical Engineering, (33 W. Thirty-ninth St., New York 18, N. Y.) **67**, No. 4, 354 (April 1948) and **67**, No. 5, 456 (May 1948).
 Nomograph for paint-film calculations. Horace A. Berman. Organic Finishing (Finishing Publications, Inc., 11 West Forty-second St., New York 18, N. Y.) **9**, No. 3, 21 (March 1948).
 Comparative correlations of $f^{\circ}F2$ with "ionospheric sunspot number" and ordinary sunspot number. M. Lindeman Phillips. Terrestrial Magnetism and Atmospheric Electricity (Johns Hopkins Press, Baltimore 18, Md.) **53**, No. 1, 79 (March 1948).
 Tensile properties of rolled silver chloride. B. M. Axilrod and J. J. Lamb. Journal of Applied Physics (57 E. Fifty-fifth St., New York 22, N. Y.) **19**, 213 (1948).

⁴ Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, \$4.50 (foreign, \$5.50); Technical News Bulletin, \$1.00 (foreign \$1.35); Basic Radio Propagation Predictions, \$1.00 (foreign \$1.25). Single copy prices of publications are indicated in the lists.

⁵ Reprints from April Journal of Research.

⁶ Available on request from the National Bureau of Standards, Washington 25, D. C. Letter Circulars are prepared to answer specific inquiries addressed to the Bureau, and are sent only on request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.

⁷ These publications are not available from the Government. Requests should be sent direct to the publishers.

